AL.2.1992-494
c.2.

ERCB Report 92-C

CANADIANA
OCT - 8 1992

NOVA Pipeline Failure

James River Interchange

Digitized by the Internet Archive
in 2015

https://archive.org/details/novapipelinefail00albe

NOVA Pipeline Failure

James River Interchange

ENERGY RESOURCES CONSERVATION BOARD
ERCB REPORT 92-C

Published August 1992

Published by

Energy Resources Conservation Board
640 - 5 Avenue SW
Calgary, Alberta
T2P 3G4

Telephone (403) 297-8311

Fax (403) 297-7040

No charge

TABLE OF CONTENTS

Page

1 BACKGROUND 1

1.1 The NOVA System 1
1.2 The James River Interchange 1
1.3 The Failure 1
1.4 Hot-tap Tees 9

2 INVESTIGATION AS TO CAUSE 9

2.1 Preliminaries 9
2.2 History of the Pipeline and Tee Assembly 13
2.3 Operating Parameters Before Failure 13
2.4 Metallurgical Analysis 13
2.5 Load Analysis 17
2.6 The Secondary Effects 18
2.7 Summary of Investigation 18

3 EMERGENCY RESPONSE 19

3.1 NOVA's Response 19
3.2 Municipal, APSS, and ERCB Response 19
3.3 Public and News Media Notification 20
3.4 Post Incident 20

4 ACTIONS TO BE TAKEN BY NOVA 21

5 THE BOARD'S VIEWS 21

5.1 The Failure 21
5.2 Emergency Response 22
5.3 Conclusion 23

FIGURES

Page

Figure 1 NOVA Corporation of Alberta Pipeline System 3

Figure 2 James River Interchange 5

Figure 3 Extent of Fire Damage Schematic 7

Figure 4 Stub and Full Encirclement Saddle 11

Figure 5 Isometric of Hot-tap Installation and New Construction 15

PREFACE

The purpose of this report is to review the information pertinent to the escape of natural gas from a NOVA pipeline and to assess whether further actions should be considered. Section 1 provides a brief background describing the NOVA system and overview of the failure. Section 2 discusses the investigation of the cause and Section 3 reviews the emergency response. The Board's views on the failure and emergency response along with the conclusions are presented in Section 5.

1 BACKGROUND

1.1 The NOVA System

NOVA Corporation of Alberta (NOVA) owns and operates an extensive gas transmission system, consisting of some 17 000 kilometres (km) of pipeline, 816 receipt meter stations and 134 delivery stations. About 80 per cent of gas transported is for export and is delivered through three major exit points, Empress, McNeill and Alberta - BC (see Figure 1). These three points handle a total of about 210 x $10^6 m^3/d$ (7.5 bcf/d).

The Alberta - BC export point is fed by the Western Alberta Mainline (WAML) and the western leg of the Foothills Pipeline (Alta) Ltd. system (which is operated by NOVA). The Empress and McNeill export points are fed in part by NOVA's Edson Mainline and the Foothills eastern leg. These two main systems have gas interchange facilities, the James River Interchange, near Sundre, Alberta, about 100 km north-west of Calgary, (see Figure 1).

The system is controlled from a control centre in Edmonton.

1.2 The James River Interchange

The James River Interchange includes metering and flow control facilities to transfer gas from the Edson Mainline to the WAML. The facilities include two 610 milimetre (mm) (NPS 24) above ground meter runs and two 406 mm (NPS 16) above ground control valve installations, connected by 914 mm o.d. (NPS 36) piping, with associated instrumentation piping. At the interchange the WAML is 914 mm o.d. (NPS 36) and the Edson Mainline consists of one 762 mm o.d. (NPS 30) pipeline and two 1067 mm o.d. (NPS 42) pipelines. The Foothills pipelines at this point are 1067 mm o.d., (see Figure 2).

1.3 The Failure

At approximately 12:30 a.m. on Wednesday, 8 January 1992 a rupture and fire occurred on the 914 mm o.d. (NPS 36) WAML. The site of the rupture was adjacent to the James River Interchange, approximately 500 m north of NOVA's Schrader Creek Compressor Station.

The fire encompassed the above ground meter runs and caused them to fail. The rupture or the fire damaged about 500 m of overhead power lines that crossed the pipeline close to the failure. There was slight damage to a pipeline which crossed above the ruptured section and no damage to any other buried pipelines in the vicinity.

Fire damage was confined to a circle-like region approximately 200 m in diameter as shown in Figure 3. The fire affected trees to the north-east, and baked about 0.5 hectares of soil surrounding the incident location to a depth of 25 mm and more. The fire destroyed the dwelling of a local resident, located about 260 m from the site. There were no injuries or deaths.

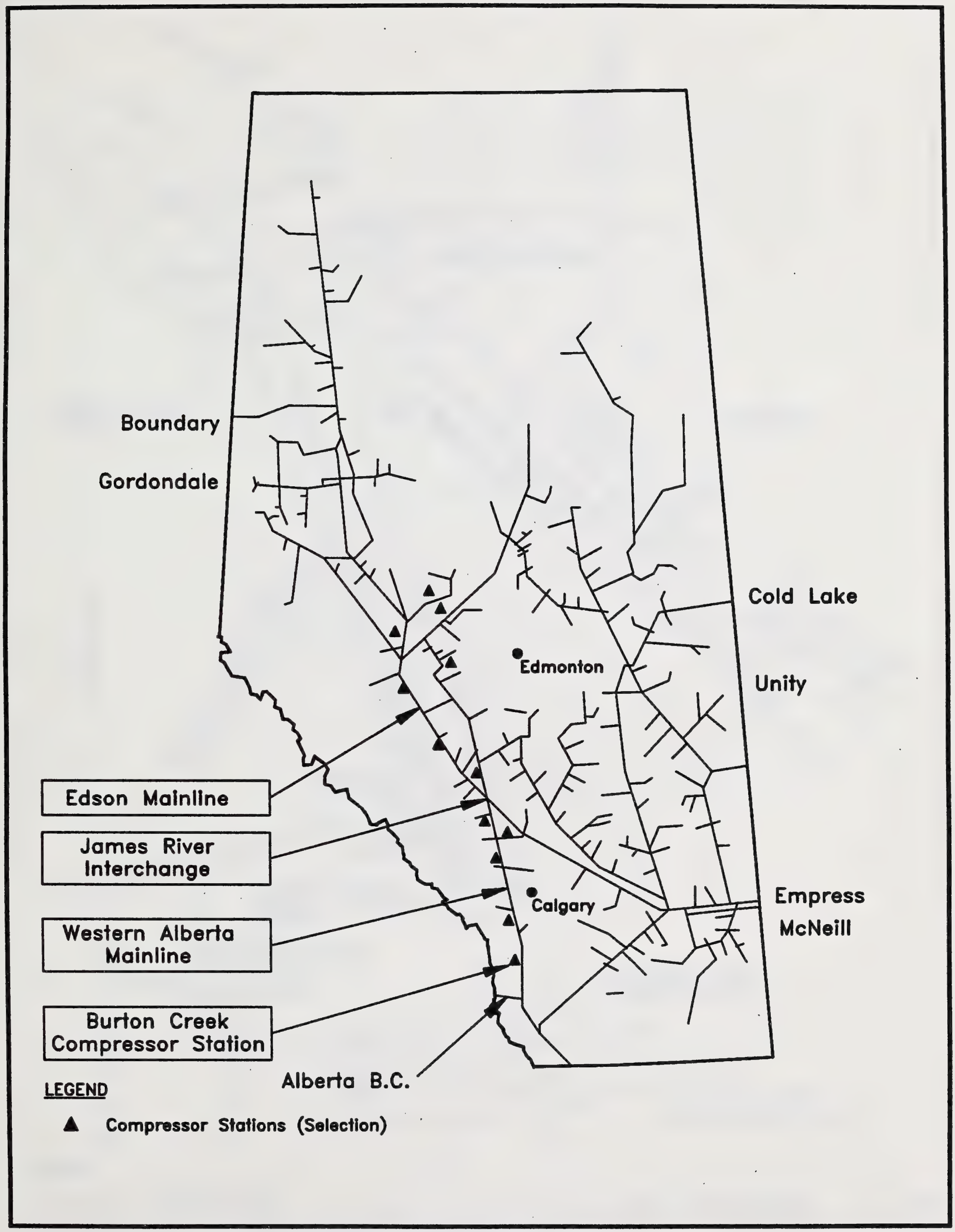


FIGURE 1 NOVA CORPORATION OF ALBERTA PIPELINE SYSTEM

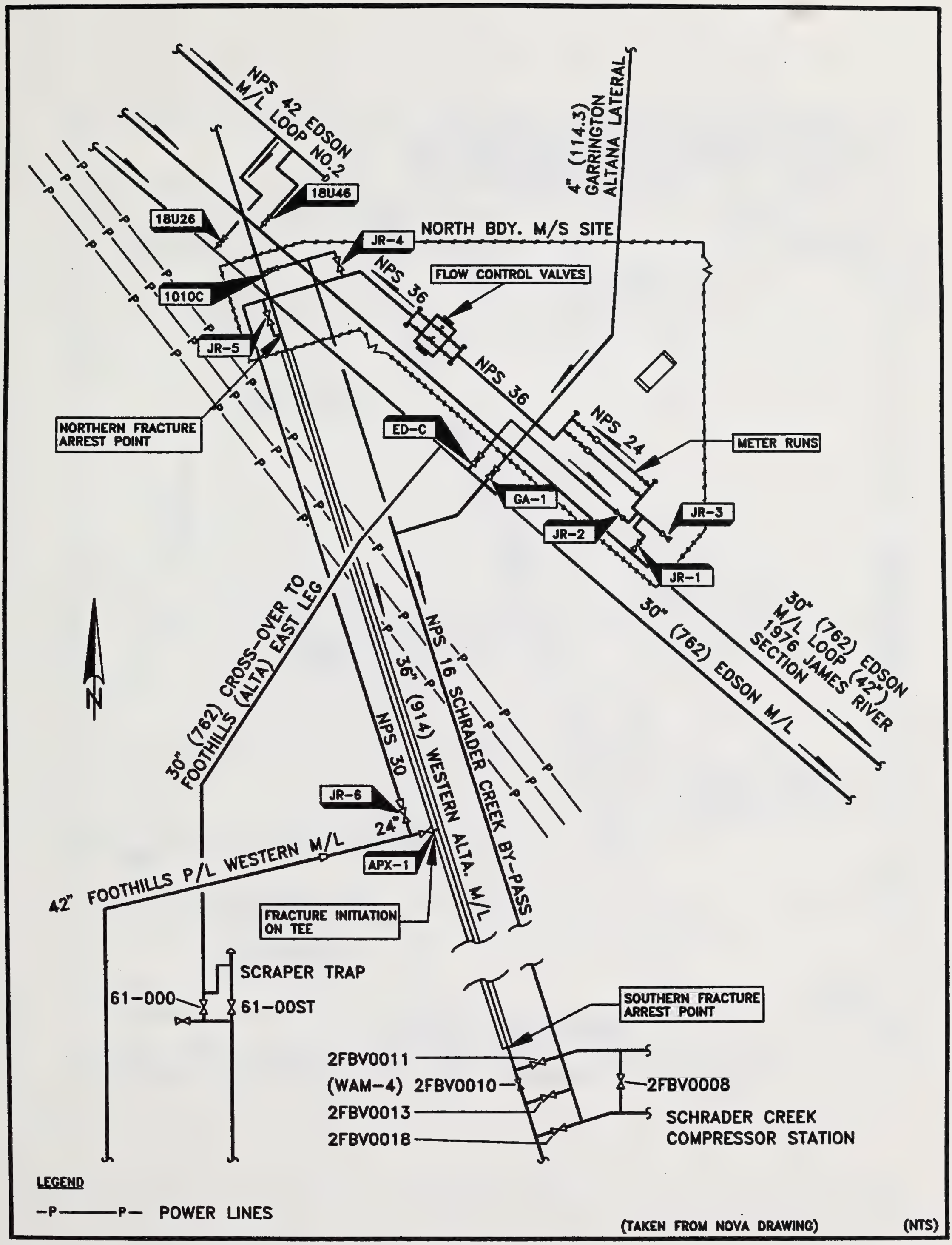

NPS 42 EDSON M/L LOOP NO.2
4" (114.3) GARRINGTON ALTANA LATERAL
18U46
18U26
NORTH BDY. M/S SITE
JR-4
FLOW CONTROL VALVES
NPS 36
1010C
JR-5
NPS 36
NORTHERN FRACTURE ARREST POINT
ED-C
NPS 24
METER RUNS
GA-1
JR-3
JR-2
JR-1
30" (762) EDSON M/L LOOP (42") 1976 JAMES RIVER SECTION
30" (762) EDSON M/L
30" (762) CROSS-OVER TO FOOTHILLS (ALTA) EAST LEG
NPS 30
36" (914) WESTERN ALTA. M/L
NPS 16 SCHRADER CREEK BY-PASS
N
JR-6
24"
42" FOOTHILLS P/L WESTERN M/L
APX-1
FRACTURE INITIATION ON TEE
SCRAPER TRAP
61-000
61-00ST
SOUTHERN FRACTURE ARREST POINT
2FBV0011
(WAM-4) 2FBV0010
2FBV0013
2FBV0018
2FBV0008
SCHRADER CREEK COMPRESSOR STATION
LEGEND
-P———P- POWER LINES
(TAKEN FROM NOVA DRAWING)
(NTS)

FIGURE 2 JAMES RIVER INTERCHANGE

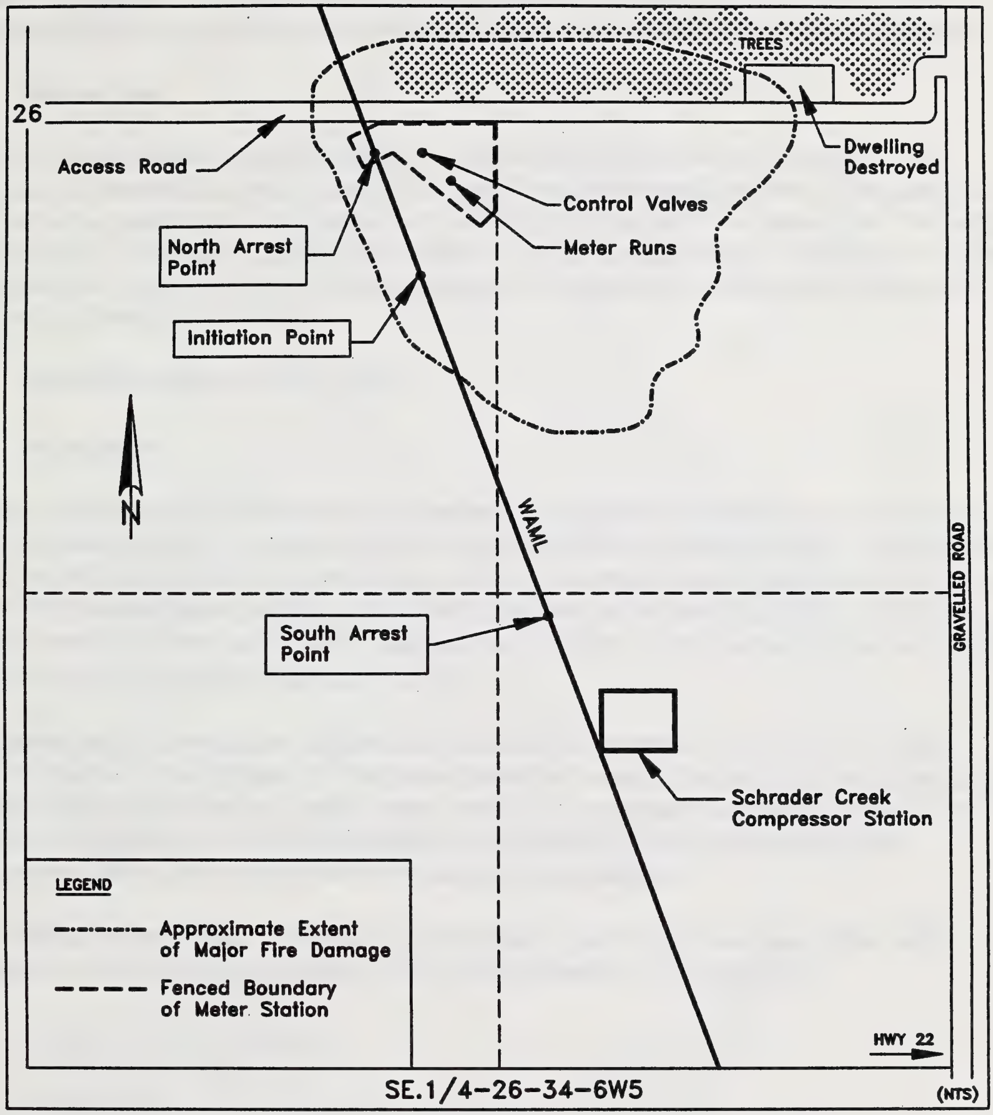


FIGURE 3 EXTENT OF FIRE DAMAGE SCHEMATIC

Because of the complexity of the pipeline system at this location, 33 valves had to be either closed or confirmed closed to isolate the affected area. The failure caused significant reduction in NOVA's delivery capabilities. The Eastern system was fully restored to service late on 10 January. The damaged pipeline was replaced and the Western system returned to full service early on 13 January.

1.4 Hot-tap Tees

A hot-tap tee is a branch connection made to a pipeline while the pipeline is in operation. The procedure is, essentially, to weld a piece of the branch pipe to the existing pipeline. Then, through a special valving arrangement, the pipeline wall is drilled or cut out inside the branch pipe. The taking out of a part of the existing pipeline would weaken it, therefore reinforcement in the form of a saddle is required (see Figure 4). Special welding procedures are required for the installation to account for the cooling effect of the gas flow.

2 INVESTIGATION AS TO CAUSE

2.1 Preliminaries

Usually in major failure investigations the Board insists on metallurgical analysis by a third party. However, the Board has knowledge of NOVA's capabilities in this regard and, subject to monitoring by Board staff, allowed NOVA to conduct the analysis. This report is based on a Board staff review of NOVA's detailed report, supplemented by staff attendance at the site of the failure, at NOVA's research centre at Airdrie, and at NOVA headquarters in Calgary. NOVA carried out the metallurgical and load analysis reported in sections 2.4 and 2.5.

Preliminary on-site investigations indicated that the source of the failure was a hot-tap tee on the WAML at valve APX-1 (Figure 2). The failure initiated at a crack in the toe of the last cap weld (see Figure 4) which propagated as a brittle fracture some 110 m northward and 310 m southward. The fracture was arrested near valve JR-5 (Figure 2) at the north end, and at the Schrader Creek Compressor Station inlet valve/by-pass valve assembly at the south end.

The resulting escape of large volumes of gas was probably ignited by friction sparks from metal fragments or rocks or by the power line. Gas ignited and burned at four locations

- the north end crack arrest site
- the rupture initiation site
- the meter runs
- the control valve assemblies.

There was no evidence of a sustained fire at the south crack arrest point.

When the preliminary site investigation was complete the fragments of the tee assembly and pieces from the meter runs were taken to NOVA's research laboratories at Airdrie, near Calgary, for analysis.

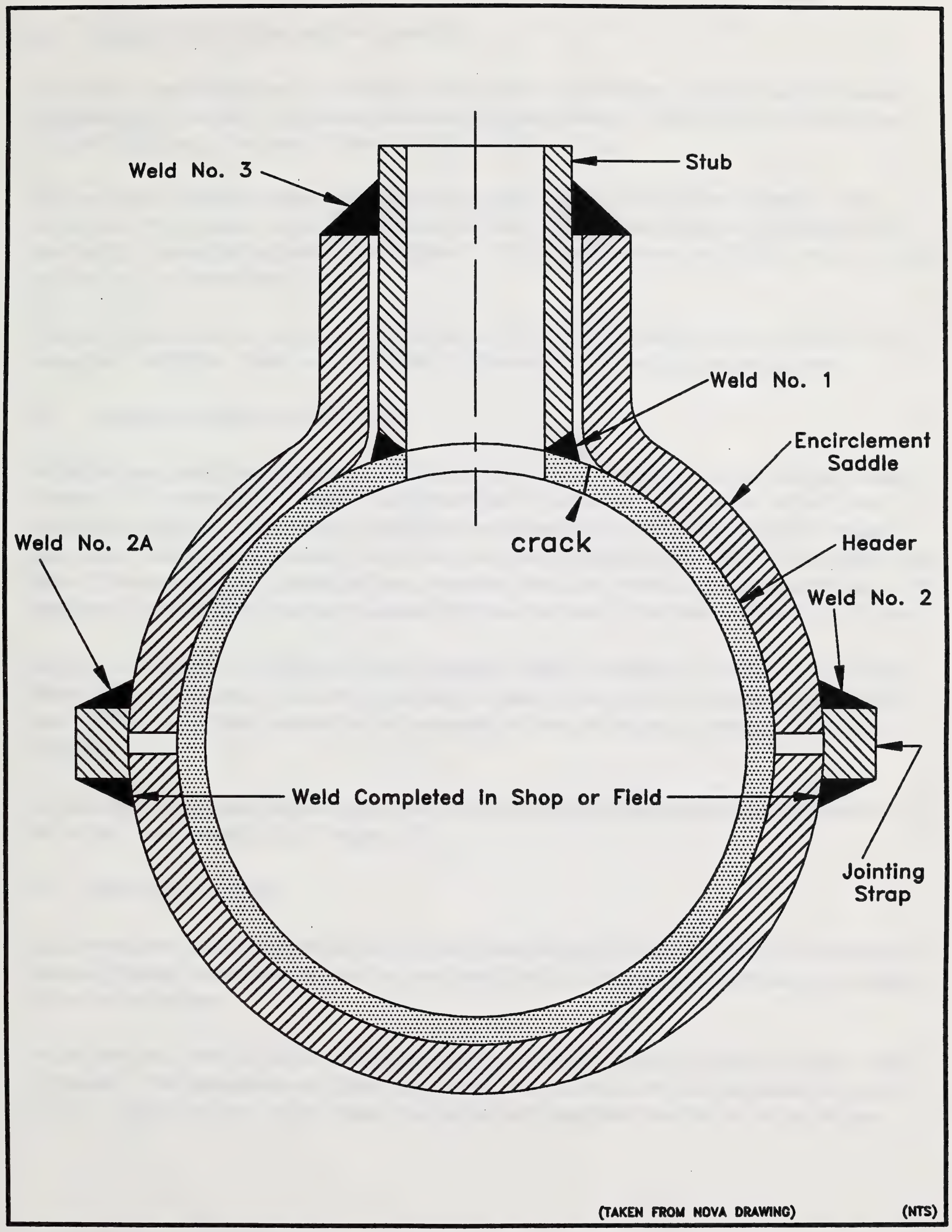


FIGURE 4 STUB AND FULL ENCIRCLEMENT SADDLE

[illegible]

2.2 History of the Pipeline and Tee Assembly

The WAML was constructed in 1961 from API 5L Grade 56 Steel pipe. The pipe met the Standard requirements of the day. The licensed maximum operating pressure of the WAML at James River is 5830 kPa (845 psi). The depth of cover in this area is about 3 m.

The tee which failed was installed by the hot-tap method in 1981, and has been in service since. In August 1991 a second tee and valve, labelled JR-6 in Figure 2, were installed on the branch from the WAML close to the original tee (see Figure 5). The distance between the WAML and the second tee and valve is approximately 6 m.

There has been one other rupture on this line, some 100 km north, which occurred in 1986 and was caused by a hill slide. There was no similarity in the mode of failure to the current incident.

2.3 Operating Parameters Before Failure

In the 24-hour period leading up to the failure the flow was variable but well below the peak capacity. However, in the evening of 7 January the Burton Creek Compressor Station on the WAML, some 200 km downstream of James River, experienced an emergency shutdown. Normally the station by-pass valve would open automatically, but in this case, due to a faulty micro-switch, the by-pass did not open. Consequently, over a period of hours, pressures rose in the system and other compressors were shut-down from the Edmonton control-centre. The fault at Burton Creek was rectified by 11:21 p.m.

The pressure record at the Schrader Creek Compressor Station, validated by readings at the Caroline North Meter Station some 4 km north (upstream) of James River, indicates that the pressure at the time of failure would have reached but not exceeded the licensed maximum operating pressure of 5830 kPa.

Significantly, this pressure was the highest the failed section had experienced since the installation of the tee and valve assembly on 31 August 1991.

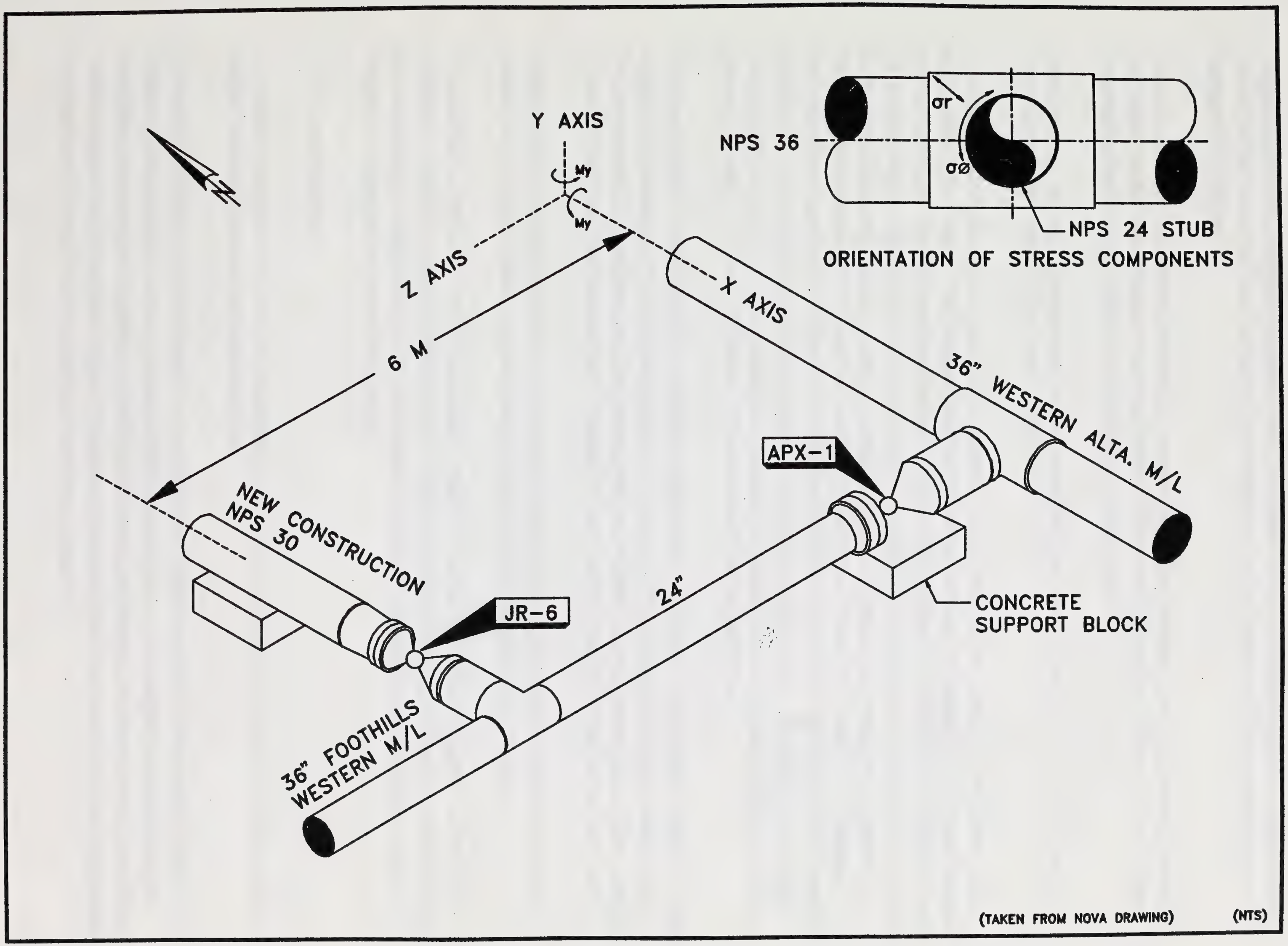
2.4 Metallurgical Analysis

The investigation was aided immeasurably by the fortunate event that one of the pieces containing an initiating fracture surface was thrown clear and buried itself in the earth, thus preventing fire damage to the fracture surface.

Brittle fracture of steel is characterized by chevron (V-shaped) markings that point back to the origin of fracture[1]. The chevrons on the failed pipe pointed back to the tee and to an initiation site at the 1 to to 3 o'clock position. In this region the fracture had propagated from two areas that did not

---

[1] See e.g. Hanson and Parr "The Engineer's Guide to Steel" Addison - Wesley.



(TAKEN FROM NOVA DRAWING) (NTS)

FIGURE 5 ISOMETRIC OF HOT–TAP INSTALLATION AND NEW CONSTRUCTION

display the chevron pattern and appeared flat. The areas were at the outside diameter surface at the toe of the stub weld, and were indicative of a defect that was in existence before the initiation of the through-wall fracture.

Scanning electron microscope fractography showed the surface features ("pop-in" features) associated with rapid, single-event fractures immediately below the pre-existing defect. There was no evidence of progressive crack growth which is associated with metal fatigue.

Metallography determined that the microstructure of the steel was typical of a 0.27 per cent carbon steel according to API 5L of the early 1960s.

There were differences in the superficial appearance of the weld on the north side compared to the south side of the branch. This indicated that the prescribed welding procedure had not been followed on the north side, the side containing the defect. The welding procedure called for an "uphand" weave for the cap weld, however, the evidence showed that a "downhand" method was used on the north side of the weld from the 2 o'clock to the 5 o'clock position. Hardness of the metal was measured by a Vickers machine with a 500 g load; the results are reported as a number of units HV. Hardness readings on the materials which buried itself showed high hardness in the weld heat-affected zone of about 500 HV, and about 400 HV in the weld metal adjacent to the defect. Readings in the parent metal averaged 210 HV. These readings are indicative of insufficient heat input during the welding process, probably as a result of the use of the downhand welding technique.

The pipe material was subjected to a fracture assessment that indicated a lower bound Charpy V-notch energy of 18 Joules at -5°C, with an average of 33 Joules at -5°C. Results of a Drop Weight Tear Test reinforced the conclusion that the material was not resistant to crack propagation. Pipe materials in the 1960 era were not required to be resistant to crack propagation, in contrast to modern steels.

Similar tests on the pipe materials which arrested the crack propagation indicate that these materials exceed the 40 Joules minimum requirement of the current CSA Standard for line pipe.

To establish an estimate of the stress or strain required to initiate the failure, the pipe material was subjected to crack tip opening displacement (CTOD) testing followed by a fracture assessment using the methodology of Appendix K of CSA Standard Z184.M86. The analysis quantified the strain required to propagate the pre-existing defect.

2.5 Load Analysis

A pipeline is subjected to loads due to internal pressure and to external loads due to transient pressure surges, thermal expansion, soil settlement, etc.

To analyze the internal pressure loads the hot-tap tee and reinforcing sleeve were analyzed using the Swanson Analysis finite element program ANSYS Version 4.4A. The analysis accommodated the installation sequence and the effect of the fit of the sleeve, and showed that the tee would have failed without a sleeve, or if the sleeve failed. The radial expansion of the pipe due to the operating pressure was less than 0.5 mm, which suggests the sleeve was a snug fit.

The external load analysis, using the Engineering Design Analysis program AUTOPIPE Version 4.1, incorporated the pipe, tee, branch layout of Figure 4. The analysis focused on the effect of vertical settlement resulting from the August 1991 excavation, and on in-plane pressure and thermal loads.

NOVA's experience indicates that concrete blocks used to support a valve during construction tend to sink into the ground over time, the load being carried eventually by the consolidated backfill under the pipe. For the installation of the new tee connection in 1991 NOVA took the reasonable precaution of not disturbing the existing valve APX-1. When the NPS 24 line was cut, the length of pipeline supporting the valve was considerably shortened. The analysis produced estimates for the stress induced by bending and by operating conditions assuming that valve APX-1 was (a) not supported, and (b) supported.

The estimates showed that if the concrete block had settled by 10 mm, allowing a 15 mm settlement at the 1991 connection, then a significant stress due to the out-of-plane bending would be induced on the failed tee at the 2 o'clock position. At normal operating pressures the combined stresses would not induce strains that would cause failure, but at the maximum operating pressure, reached at the time of failure for the first time since the 1991 installation, the strain would exceed the value required to propagate the pre-existing defect, as determined by the analysis referred to in section 2.4.

2.6 The Secondary Effects

The major fire on the WAML was at the north arrest point, and the gas emitting from the ruptured pipeline would be directed almost horizontally. The initial explosion destroyed the instrumentation controlling flow through the meter station, causing gas to flow through both meter runs. Burn patterns indicate that meter run #2, the westerly run, failed first due to localized overheating. The temperatures required to cause observed microstructural changes in the pipe metal could only have derived from a gas source, most probably from the north crack arrest point or from instrumentation piping at valve ED-C. The failure caused the meter run to shear off at the south riser and the run was propelled in a SE direction some 50 m. The gas escaping from the riser was directed vertically upwards causing the most spectacular flame. This occurred some 15 minutes after the initial failure.

Shortly afterward meter run #1 failed, but as the pressure in the run was by now much less it was not ejected. Flames from meter run #1 were directed horizontally at the control valve building, which caused the building to collapse and the assemblies to catch fire. The pipe did not rupture.

The fire at the north arrest point also resulted in a fire at the vortex meter on the NPS 30 crossover.

2.7 Summary of Investigation

The investigation leads to a plausible explanation of the cause of failure.

The hot-tap tee installed in 1981 had a welding fault in the form of a crack. The crack remained in a sub-critical stress state until the installation of the second tee in 1991. The installation required excavation around the NPS 24 branch which removed some support, and assuming that the concrete slab under valve APX-1 had sunk about 10 mm, the crack in the failed tee received an added stress that became critical when the operating pressure reached a high enough level, even below the maximum operating pressure.

The assumption in the argument is necessary because the ground around the failed tee was disturbed in the explosion, so there is no direct evidence of the settlement.

The delayed failure also could be attributed to gradual settlement under the new installation and valve APX-1, which also would cause a critical stress regime to gradually accumulate.

3 EMERGENCY RESPONSE

Emergency response to this incident included NOVA, Alberta Public Safety Services (APSS), municipal, and ERCB involvement.

3.1 NOVA's Response

Immediately following the incident, NOVA operating technicians in the James River area provided interim site coordination while a site commander was designated and dispatched to coordinate activities in the area. The immediate incident site was secured by NOVA to ensure no one was exposed to unnecessary risk of injury. A nearby resident left his house after being awakened by the rupture and was assisted by NOVA operating technicians. The house was eventually destroyed by the subsequent fire.

NOVA's response to the incident was coordinated through three emergency operation centres; one in Airdrie, one in Rocky Mountain House (both established within 40 minutes of the incident) and a third, involving NOVA's senior management team in Edmonton (established within 1½ hours of the incident).

NOVA notified the RCMP in Sundre by 1:10 a.m. and contacted connecting pipeline operators upstream of the affected area in order to prevent continuation of feed to their line.

Communication with the ERCB from all NOVA response centres continued throughout the emergency.

3.2 Municipal, APSS, and ERCB Response

This information was collated from a post-incident debriefing and using logs from various agencies involved.

The APSS duty officer in Edmonton was notified of the incident by a landowner at 12:50 a.m. APSS notified the ERCB Red Deer Office at approximately 1:00 a.m. and by 1:10 a.m. an ERCB inspector was dispatched to the site. He arrived at a roadblock established by the RCMP at 2:10 a.m. and was accompanied to the incident site by NOVA at 3:00 a.m.

The RCMP had responded to the incident site by 12:50 a.m., and were manning road blocks and assisting with evacuation throughout the emergency.

Firefighters from Caroline, Sundre, Olds, Bowden, and an industrial firefighting unit had responded to the fire without being contacted by NOVA.

At approximately 12:50 a.m. evacuation of approximately 18 families and the Dilcon workers at Shell's Caroline Construction Camp had been initiated by NOVA operating technicians on site, in consultation with the RCMP and Dilcon Engineering.

The Town of Caroline Director of Disaster Services opened the Caroline evacuation centre at approximately 1:20 a.m., after notification of the incident by the local fire department. By 3:20 a.m. the evacuation centre was overwhelmed by evacuees from the Shell Camp and a second evacuation centre was activated. At 4:30 a.m. the Dilcon Construction personnel were advised that it was safe to return to their camp.

The ERCB Red Deer Area Office was opened at 1:30 a.m. and contact was established with APSS in Edmonton and the NOVA emergency operations centres. The local district representative for APSS was called to the ERCB Red Deer Office at 3:50 a.m. and arrived at approximately 5:00 a.m. The ERCB contacted the local Occupational Health and Safety representative at 4:50 a.m.

3.3 Public and News Media Notification

At 2:50 a.m. NOVA in Rocky Mountain House was requested by the ERCB to issue a press release regarding the incident as soon as possible.

NOVA's contact with the local radio station commenced around 4:00 a.m. and by 6:30 a.m. seven radio stations had been contacted and provided with information. NOVA continued to respond to a multitude of calls from all over Canada and the US.

The ERCB Communications Manager was dispatched to the ERCB Red Deer Office. He arrived at 5:20 a.m. The ERCB responded to approximately 16 news media enquiries.

Many concerned and frightened citizens called the RCMP and the local hospital. Both phone systems were overwhelmed by public requests for information.

3.4 Post Incident

An aggressive community relations program was initiated by NOVA after the emergency. It included post incident stress debriefing and visits to all residents within a 6 km radius of the incident.

Meetings were held with industry and community groups, regulators, civic officials, and elected representatives to explain the incident and answer questions.

APSS, with ERCB's concurrence, conducted a debriefing of the incident, attended by NOVA and all the industry, government, and municipal responders involved in the emergency.

4 ACTIONS TO BE TAKEN BY NOVA

NOVA is pursuing the following recommendations made by its staff:

a) Additional stress and fracture analysis to determine the significance of weld toe cracks in hot-tap tees with high branch to run diameter ratios.

b) The replacement by July 1992 of three similar hot-tap tees on the WAML, at places where adequate crack arrest capabilities are absent.

c) A risk assessment to determine the appropriate remedial action, should the analysis in a) identify a generic integrity concern.

d) A review of the design requirements and procedures with respect to hot-tap construction and construction near hot-tap installations, with respect to

    i) soil settlement,
    ii) proximity to other tie-ins,
    iii) weld quality assurance, and
    iv) material properties.

e) A review of emergency response procedures to address

    i) more timely contact with local residents and municipal officials,
    ii) more timely information to the news media,
    iii) the assignment of a community relations coordinator to the site, and
    iv) a contact program to help emergency response officials to understand the nature of natural gas pipeline emergencies.

5 THE BOARD'S VIEWS

The Board commends NOVA for conducting a very thorough investigation and analysis of the failure. The analysis provides a logical explanation about the initiating events and the likely underlying cause of the failure.

5.1 The Failure

The Board accepts that the fundamental cause of the failure is the deviation from the welding procedure prescribed for the hot-tap tee installation. It is satisfied that the crack induced by the faulty procedure would have remained in a sub-critical mode were it not for the construction activities of August 1991. From that time on the defect awaited only a change in pressure regime, or further settlement of the valve APX-1, to reach critical dimensions and fail.

The Board through its involvement in the standards writing process and its monitoring of industry practices is satisfied that welding practices are generally adequate. However, it recognizes that the welding process, particularly on and related to component installation, is a human process and, as such, subject to human frailties, and therefore requires close inspection. In this instance inspection was lacking and it concerns the Board that welding on such an installation was not subjected to the most thorough inspection.

As a monitoring agency the Board relies on the written procedures and processes being followed and the quality assured by adequate inspection. The Board observes that NOVA has improved its inspection requirements since 1981, but it concurs with the NOVA recommendation that weld quality assurance be the subject of review. Recently published Alberta failure statistics (ERCB Publication 91-G) indicate that failures at welds account for 5 per cent of all failures. Therefore, the Board will stress the importance of proper weld inspection with the standards writing bodies and industry organizations.

NOVA's analysis indicates there are no similar configurations of installations on the WAML, but it has identified three installations where risk to the public justifies replacement with components welded into the main line. The Board concurs with NOVA's replacement program and will monitor NOVA's review of design and procedures regarding hot-tap construction, including the settlement of valve supports, and its use in risk assessment.

The Board is concerned that 33 valves need to be closed to isolate the James River Interchange. The Board will therefore require NOVA to analyse the design of the interchange to explore the possibility of reducing that number.

5.2 Emergency Response

The Board is satisfied that NOVA responded promptly and effectively to contain the incident. The Board recognizes that the site repair work was well organized with every effort made to prevent injury and to mitigate impact to customers and connecting pipeline operators. NOVA's post-incident community relations efforts were comprehensive and appeared to be effective.

An apparent breakdown in the notification protocol of Provincial authorities in Edmonton contributed to a weakness in municipal coordination at the local level. This, in turn, contributed to the delay in informing and advising the public and the news media about the incident.

The Caroline region is a primary sour gas producing area. Residents of the area are intensely involved in the development and operations of the energy industry and are highly aware of the hazards associated with sour gas. Public involvement with recent sour gas developments has heightened the expectations of this community regarding emergency preparedness and communication. The Board appreciates that this incident did not involve sour gas. However, it believes that if NOVA had recognized earlier the sensitivities of the area, there may have been reduced public confusion and concern. The Board believes that the affected public, and the public who perceive themselves to be affected, should be informed as soon as possible and with sufficient detail regardless of whether the event involves sour gas.

The Board is concerned that, although NOVA complied with all current requirements, there was some lack of coordination amongst those involved in the response. The Board believes that effective emergency response requires maximum consultation and cooperation between the operator and other responders assisting during an emergency. The Board believes that the existence of three NOVA response centres may have unduly complicated the communication and decision-making process. The Board considers one centre for the coordination of all aspects of emergency response to be more effective.

5.3 Conclusion

The Board is satisfied that the cause of the failure has been determined. However, the Board believes that the investigation and analysis of the incident has pointed out areas that require further investigation:

1. Weld inspection
2. The total design of hot-tap installations.
3. The coordination of response to emergencies.
4. The isolation of the James River Interchange

The Board will pursue, with NOVA and others, resolution of these four areas.

Although Alberta's pipelines have an excellent safety record, this failure points out the continuing need for quality assurance at all stages of pipeline construction and operation. This event may have been prevented by strict adherence to a proven welding procedure. The Board encourages the industry in its training activities to use this failure as an example of what can happen when one of many procedures used in pipeline construction is not carried out properly.